AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLXXVI.

(Vol. XIII.—March, 1884.)

PRELIMINARY REPORT OF THE COMMITTEE ON A UNIFORM SYSTEM FOR TESTS OF CEMENT.*

PRESENTED AT THE ANNUAL MEETING, JANUARY 16TH, 1884.

WITH DISCUSSION.

To the American Society of Civil Engineers:

Your Committee, appointed to devise a uniform system for tests of cement, respectfully submits the following preliminary report.

In response to the request of the Secretary of the Society, made last year, samples of mortar sand have been received by the chairman of said

*This paper was presented by the Committee at the Annual Meeting as a preliminary report, and was accepted as such by vote of the meeting, the Committee being continued. The Committee was as follows: Messrs. D. J. Whittemore, J. Herbert Shedd, Q. A. Gillmore, Alfred Noble, F. O. Norton, W. W. Maclay, Eliot C. Clarke.

Committee, kindly sent by members from localities indicated in an appendix to this report.

It will be observed that no samples have been received from the Pacific slope or from Canada.

The purpose of the Committee in making this collection is that a standard sand may be found in deposits somewhat widely distributed over this continent, that will give uniform results in mortar tests; therefore it is quite desirable to secure typical sands from regions not covered by the samples received, before commencing any mortar tests of the sands at present collected.

Bearing in mind the labor and time necessary to make such collection and examination, we feel that it is due the Society that a mode of testing should be formulated and recommended for adoption, without further delay, as follows:

I.—In selecting samples of cement for experimental purposes, take the same from the interior of original packages at sufficient depth to insure a fair exponent of quality, and store the same in tightly closed receptacles impervious to light or dampness until required for manipulation, when each sample of cement should be thoroughly mixed by sifting or otherwise, that it may be uniform in character throughout its mass.

II.—Ascertain the per cent. by weight of each sample that is rejected by sieves of 2 500, 5 476 and 10 000 meshes to the square inch respectively, the first mentioned sieve being of No. 35, the second of No. 37, and the third of No. 40 wire gauge.

III.—For tests of mortar composed in part of sand, the sand should be sharp, well washed and dried, rejecting all that will not pass the sieve of 400 meshes to the square inch, and that will pass a sieve of 900 meshes to the square inch; the wire gauge of the former sieve to be No. 24, and of the latter No. 28.

IV.—The proportion of sand for mortar of each briquette should be carefully determined by weight, and thoroughly and intimately mixed with the cement in a dry state before water is added, and, so far as possible, all the water of mixture should be added at once that is necessary to produce the desired consistency of the resulting mortar, and thereafter

the manipulation by the spatula or trowel should be rapid and thorough, and care should be taken to introduce the mass into the molds and complete the molding process before incipient setting begins.

V.—Ordinary fresh and clean water having a temperature acquired when exposed in open vessels in an atmosphere ranging between 60° and 70° Fah. should be used for water of mixture and immersion of molded samples.

VI.—For determination of strength, tensile tests are recommended; and the form and size of briquettes and clips to be used, shown by the Plates XVI and XVII, are thought proper for this purpose.

VII.—It is desirable that the bulk of given weights of cements be ascertained, and the following method is recommended for that purpose: Procure a cylinder six inches long, having an interior section equal to an area of two square inches. Sifting the cement to be measured so that it may not be compact, weigh carefully 5 ounces if of Portland cement, and 4 ounces if of American hydraulic cement, and pour the same into the cylinder, which should stand upright with its lower end resting upon a close-fitting and suitable base; then, without shock or sudden impact, lower a closely fitting piston, moving without friction, slowly down the cylinder on to the cement, said piston and its attachments to weigh exactly 50 pounds. After resting thereon for one minute, remove the same and ascertain the bulk of cement thus compressed. When sand is used in the fabrication of mortars, ascertain the weight of an equal bulk of sand to that of the cement used in connection therewith, said sand to be shaken until its bulk remains unchanged before weighing.

VIII.—In applying stress on briquettes, do not allow in the commencement a strain to exceed one-half the estimated breaking strength of the best piece, and thereafter increase the same regularly at the rate of about 200 pounds per minute until rupture takes place. If it is desired to compare the strengths of cement broken by different testing machines, it is recommended to compare the machines themselves by breaking similar lots of briquettes on each, in order to determine their peculiar differences.

IX.—For Portland cement tests, the following method is recommended: Take enough cement to make five briquettes, 1 part cement, 3 parts sand, by weight; ten briquettes of neat cement and two cakes of neat cement 2 or 3 inches in diameter, about $\frac{1}{2}$ inch thick, with thin edges.

X.—Note the time in minutes that these cakes, when mixed with water to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by Gen. Gillmore, viz.: $\frac{1}{12}$-inch diameter wire loaded with $\frac{1}{4}$ of a pound, and $\frac{1}{24}$-inch diameter wire loaded with 1 pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted or if cracks show themselves at the edges. This is the test to show if the cement remains constant in volume, and is very important. The remaining cake should be kept in the air and its color observed, which for a good cement should be a uniform bluish gray throughout, yellowish blotches indicating poor cement. The color of the cement when left in the air indicates the quality much better than when the cement is put in water.

XI.—Make five briquettes composed of 1 part of cement and 3 parts of sand (by weight). Also make ten briquettes of neat cement; the molds in each instance, while being charged and manipulated, to be laid directly on glass, or slate, or some other non-absorbent material.

XII.—The proportion of water, by weight, for the neat cement should be from 20 to 25 per cent. or more, according to the fineness, age or other condition of the cement and the temperature of the air.

XIII.—The desired mixture is a stiff plastic mortar, and when reached under certain conditions, a very slight addition of water will sensibly diminish the tensile strength, especially for the seven-day test. As the age of the briquettes increases, the injurious effect of too much water in gauging is less marked. When gauged, 1 part cement to 3 parts sand, by weight, the water required should not vary much from 10 per cent. of the combined weight of the cement and sand.

XIV.—The molds, when filled, should be pressed down firmly and struck off level; uniformity in this operation can only be obtained by practice. A damp cloth should be kept over the briquettes until they are hard enough to immerse in water.

PLATE XVI.
TRANS. AM. SOC. CIV. ENGRS.
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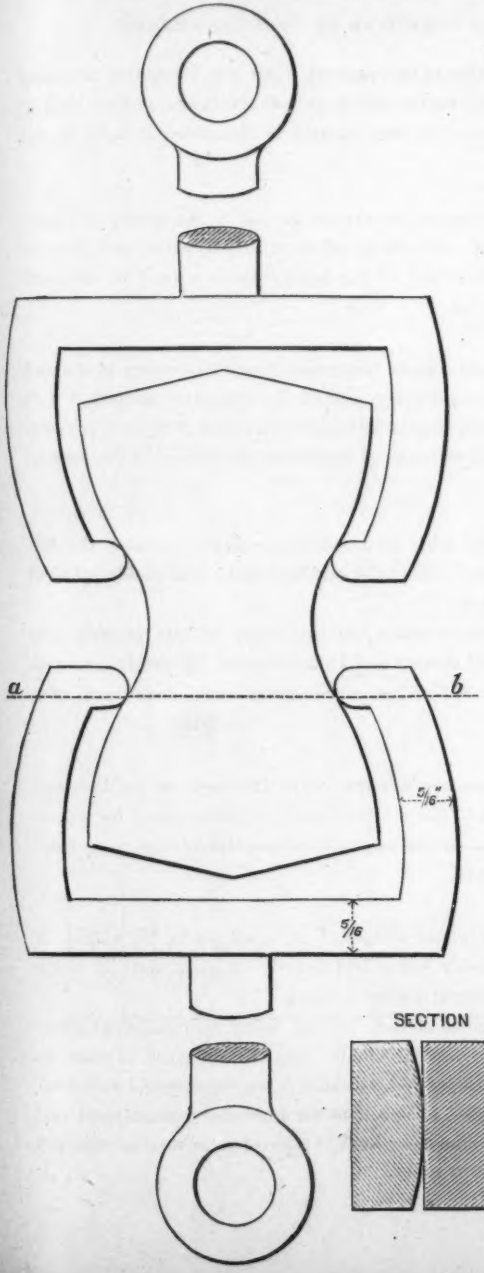
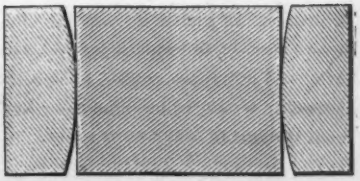
REPORT OF COMMITTEE
ON TESTS OF
CEMENT.



STANDARD FORM FOR
BRIQUETTE AND CLIPS,
AS RECOMMENDED BY THE
COMMITTEE ON A UNIFORM SYSTEM
FOR TESTS OF CEMENT.

SECTION THROUGH *a-b*



XV.—The molds should be removed when the briquettes are hard enough to stand it; and for the sake of uniformity, the briquettes, both of neat cement and mixed with sand, should be immersed in water at the end of 24 hours.

XVI.—The briquettes should always be put in the testing machine and broken immediately after being taken out of the water, and the temperature of the briquettes and of the testing room should be constant between 60° and 70° Fah.

XVII.—Half the neat cement briquettes should be broken at the end of 7 days and 28 days respectively, and all the briquettes gauged, 1 part cement and 3 parts sand, should be broken at the end of 28 days, in order to determine the tensile strength of each from the average of five breakings.

XVIII.—For making tests of American hydraulic cements, the following method is advised—using the standard mold and clutch advised for Portland cement tests:

Take enough cement to make ten briquettes of neat cement, five briquettes 1 part of neat cement and 1 part of sand, by weight, and two cakes of neat cement, 2 or 3 inches in diameter, about $\frac{1}{2}$ inch thick, with thin edges.

XIX.—Treat and observe the two cakes the same as for Portland cement; the cake kept in the air will be of a uniform color for a good cement, light or dark, according to the character of the rock from which the cement is made.

XX.—Make five briquettes composed of equal parts, by weight, of cement and sand, the molds being laid directly on glass, slate, or some other non-absorbent material during molding.

Also make ten briquettes of neat cement, using only sufficient water to make a stiff plastic mortar (the molds being laid on glass, or slate, as before stated), and when filled to be pressed down forcibly and struck off level, and otherwise treated as specified for Portland cement until immersed in water, which immersion should take place as soon as removed from the molds.

PLATE XVII.
TRANS. AM. SOC. CIV. ENGRS.
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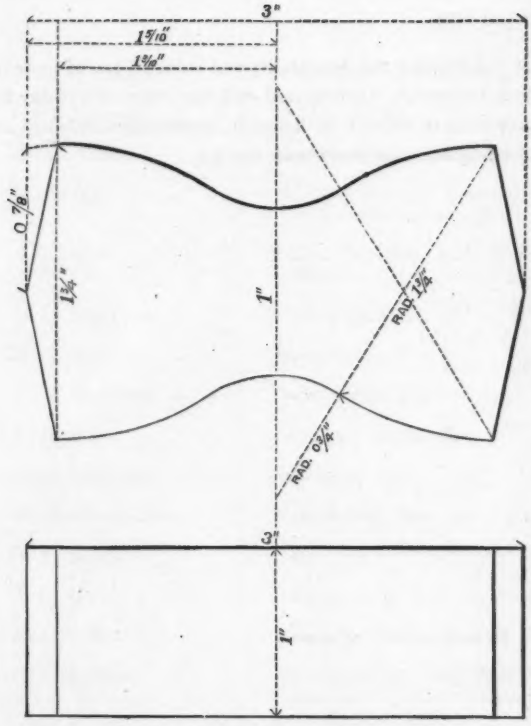
REPORT OF COMMITTEE
ON TESTS OF
CEMENT.



DETAILS FOR BRIQUETTE,
AS RECOMMENDED BY THE COMMITTEE
ON A UNIFORM SYSTEM FOR
TESTS OF CEMENT.

XXI.—The briquettes should always be put in the testing machine and broken immediately after removal from the water, and the temperature of the briquettes and of the testing room should not exceed 70° nor be below 60° Fah.

XXII.—Half of the neat cement briquettes should be broken at the end of 24 hours, and the remainder at the end of 28 days, and all the briquettes composed of equal parts of sand and cement at the end of 28 days, and from these results the average strength to be determined in each series of tests.

XXIII.—Admitting the desirability and value of the 24-hour tests of neat cement briquettes, we esteem of still more value the 28-day tests of similar briquettes in connection therewith, as showing continued activity and as affording an index of ultimate energy.

APPENDIX.

STATEMENT OF SAMPLES OF SAND RECEIVED FROM LOCALITIES AND PERSONS INDICATED.

NUMBER OF SAMPLES.	FROM WHOM RECEIVED.	LOCALITY TAKEN FROM.
18	Wm. P. Judson.	South shore of Lake Ontario.
2	C. H. Latrobe.	Baltimore, Md.
6	W. F. Foster.	Near Nashville, Tenn.
4	H. Bissell.	Newburyport and Lynnfield, Mass., and North Conway, N. H.
5	A. Anderson.	Lake Superior and Yellowstone River.
1	S. L. Smedley.	Philadelphia, Pa.
4	D. E. McComb.	Washington, D. C.
1	T. H. Moorhead.	Jacksonville, Fla.
3	A. Noble.	Sault Ste. Marie, Mich.
1	John Whitelaw.	Cleveland, O.
1	Knight & Bontecou.	Kansas City, Mo.
3	S. F. Lewis.	Near Lake Pontchartrain, La.
2	J. P. Allen.	Charleston, S. C.
1	Robert Moore.	Mississippi River, near St. Louis.
5	C. F. Loweth.	Raccoon River, near Des Moines, Ia.
1	J. H. Cunningham.	Standard sand used by J. Grant, M. Inst. C. E., London, Eng.

In addition to this list of sands, the Chairman has collected samples from Wisconsin and adjoining States.

DISCUSSION.

F. Collingwood, M. Am. Soc. C. E.—The very careful method, described in the report, of measuring struck me. There is one point that might not have been thought of; that is, the humidity of the material. We know that cement does absorb moisture. It may be sifted very finely, it may be measured carefully, and yet have a different weight for the same amount of material, unless the state of humidity was taken into account. I do not think that in this preliminary report that point was touched upon. I do not see how an exact weight could be secured, even by the careful method described, if humidity is not taken into account. Unless we get the specimen correctly into the machine, we do not get the correct result. That is a point that ought to be carefully attended to.

D. J. Whittemore, President Am. Soc. C. E.—In the preliminary paragraph of the report, a method of selecting samples is described; taking them from the interior of the packages, putting them in closed boxes, away from light, and keeping them until manipulation takes place. As to the form of briquette given in this preliminary report, it is substantially that recommended by Mr. John Grant, M. Inst. C. E., of London, which he has found to be the one that gives the most uniform results. At the last Annual Convention, it may be remembered that I presented a machine for eliminating cross strains in testing cements. While it does that work, it also does away largely with the personal equation in the matter of manipulation. The machine is one of considerable expense. I should like to see it adopted, but I take a common-sense view of the matter. I think it would require a man of intelligence for the manipulator, and it would require a considerable expense in its manufacture. Looking through the experiments of Grant for the last few years, I find that he brings the average variation down almost to the figure I get for mine, so I very willingly conceded that the form of briquette mold referred to in the report should be recommended. I should be very glad to see the Society adopt that in lieu of the one I brought forward some years ago. The subject is not brought out in the report, but by examination of the drawing you will see that the later ideas as to the form are fully covered by it.

James Owen, M. Am. Soc. C. E.—There is one point that has been developed in my experience, and that is in the manipulation of the ma-

terial itself. I found in many cases the available sectional area was reduced from the fact of bubbles being inside the cement; and the only way I could get rid of them was to work the cement industriously to get them out; and when I got them out, I knew that the whole sectional area was solid material.

ELIOT C. CLARKE, M. Am. Soc. C. E.—I would say on the part of the Committee, and certainly on the part of one member of it, that the Committee would be happy to receive suggestions from members of the Society who are familiar with the practice of testing cement, as to what they consider important in making tests. There are a great many points in regard to testing cement we have simply given, but which are almost impracticable for use by engineers in general, who want to test cement in places where they have not much time; they want to get an idea of whether their cement is good or not, and have not time to go into all the minute careful manipulation that would be practicable in the laboratory, but which is not practicable in the ordinary engineer's office, or in the field. In making this report we have to compromise between niceness of test, and what is practicable for engineers to do.

Our members may have noticed that the density of the mixture is left in our report to the manipulator. He makes a stiff, plastic mortar. One can get a more uniform result by pressing the mortar into the molds by certain known pressures and weights. I have done that myself, by having a machine for pressing the mortar in with a certain definite pressure and weight; but it took so long that I should consider it impracticable for ordinary testing such as engineers have to do.

F. COLLINGWOOD, M. Am. Soc. C. E.—There are two things we want to determine by this investigation: not only the practical methods, but also the theoretical. We know there has been a great diversity of opinion, and no two experimenters have been able to arrive at the same results, and the differences are due, even where they have been careful, to differences in method, and to neglect of little things which have been enough to cause decided differences in the result. That is important as a means of judging accurately of various cements. We might find it desirable to make a few such experiments if we are going to take a large contract for cement. I take it we have to distinguish between those two ideas.

J. J. R. CROES, M. Am. Soc. C. E.—One suggestion made by the Committee seems to me a very important one; that is, that the test

should be made when the cement has stood for a much longer time than 24 hours. I had a case a few days ago of a cement that was sent to me to be tested. The briquettes were made up, exposed 30 minutes in air, 24 hours in water, and broke at 125 pounds per square inch. The cement looked very good. Those briquettes were lying in the office for five or six days, and at the end of that time the broken pieces were put in water, and they began to crumble, and within 48 hours they had all gone to pieces. But the cement was, apparently, on the 24-hour test, perfectly good, and perfectly good at the time it was put in the water, at least a week after the test was made; but it went to pieces within 48 hours.

D. J. WHITTEMORE, President Am. Soc. C. E.—The point made by Mr. Collingwood, I think, is well taken as to something more definite than the usual method of testing cement, being applied, perhaps, only occasionally, however. That might involve the Committee in devising methods for laboratory experiments, which, I think, the resolution hardly contemplated. In case anything of that kind should be contemplated, then I think the wording of the report—in fact, the whole report—would be changed and made much more voluminous.

JAMES OWEN, M. Am. Soc. C. E.—The great trouble I have found is in getting a good standard, which can be referred to with assurance. In works where one wants to have good cement, where it is stated that such or such is not good, it leads to an endless controversy. It seems to me that the idea of having the Committee prepare proper standard methods of testing for general work is a good thing.

WILLIAM E. WORTHEN, M. Am. Soc. C. E.—I have had occasion sometimes to use a cement that is not quick-setting, and I put plaster of Paris with my cement. I told the men to put in plaster of Paris where there was a wet bottom and make a concrete, and it made a very hard cement.

ELIOT CLARKE, M. Am. Soc. C. E.—You can mix cement with almost anything. I have used on the improved sewerage work in Boston all kinds of cement—the American cement, the Roman cement, the Portland cement—and mixed them altogether. If we want a quick-setting cement, we make it as quick-setting as we want it, by mixing it with the Roman cement. Sometimes we mix clay with it, and sometimes grease. The grease destroys the strength somewhat, but still it has some strength. We find we can mix cement with almost anything, and different kinds of cement together.

D. J. WHITTEMORE, President Am. Soc. C. E.—I should hardly think

that the use of grease is entirely new in the use of cement. I understand that the ancients used olive oil and hog fat in the cement used to line their aqueducts.

WILLIAM E. WORTHEN, M. Am. Soc. C. E.—I am still laying cement in the way I referred to, and I am satisfied it is going to be good. I put in lime enough to warm it, and I never had any trouble with it. I laid at Long Island City a dome 50 feet in diameter, and about 25 feet rise, without a centre, in the middle of December, and put about one-third of lime with it, and to this day it stands there, in good condition. It has been there many years. That is a pretty large proportion, but it was pretty cold weather when the work was done.

D. J. WHITTEMORE, President Am. Soc. C. E.—The relative importance of the two cements, the American hydraulic cement and the Portland cement, might as well be brought out at this meeting. I am placed in a position to assert pretty confidently that the amount of American hydraulic cement annually used in this country this side of Buffalo is nearly two million barrels; that made on the other side amounts to about 1½ million barrels a year. The amount of Portland cement used in this country is, as you know, very much less than that; that is to say, perhaps half a million barrels would cover the entire annual consumption of Portland cement on this continent at the present time. So when we are devising methods for testing cement, we want to bear in mind what a very large proportion of the cement used is the product of our own country.

The following communication was read:

J. ALBERT MONROE, M. Am. Soc. C. E. (through the Secretary).—I desire to lay before the Society the following statement of facts, and propound the question—why was it?

The New York, West Shore and Buffalo Railway purchased from the Walkill Railroad Company the right of way acquired by them from Kingston to Albany. Construction for a single track railway had been commenced by the latter company. At Gleneric, a point on the Esopus Creek, piers had been built for a bridge. They were about 25 feet high, of ordinary first-class masonry, with backing, laid in cement. The construction and location of these piers not being satisfactory, they were condemned and taken down.

During the process of demolition I observed that the cement mortar which appeared to have been freely used had not set, though it had been

in place for something like a year, and that it was shoveled out by the workmen like damp loam. I gave the matter no particular thought, except that this condition of the mortar facilitated our work, until one day, when my attention was called to the fact that it set very quickly after exposure to the air. Making experiments then, I found that after a half-hour or an hour's exposure the set would be as hard as could be expected of the very best cement mortar. It is the only instance of the kind that ever came under my observation. I lay it before the Society for the information of those who have never had like experience, and discussion, if considered worthy of it.

The cement used in the mortar was that of the Hudson River Company, manufactured at Flatbush, on the Hudson River.

The proportion of cement to sand I cannot tell.

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CCLXXVII.

(Vol. XIII.—March, 1884.)

THE RAILWAY PILE AND PONTOON BRIDGE ACROSS THE MISSISSIPPI RIVER AT PRAIRIE DU CHIEN, WIS.

By JOHN LAWLER, F. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, ST. PAUL, MINN., JUNE 20TH, 1883.

WITH DISCUSSION.

The Railway Pile Pontoon Bridge, which is the subject of this paper, was built in the year 1874, across the Mississippi River, between Prairie du Chien, in the State of Wisconsin, and North McGregor, in the State of Iowa, for the purpose of connecting the divisions of the Chicago, Milwaukee and St. Paul Railway Company, terminating respectively at the points named. The river here is divided, by an interjacent island, into two channels, both of which are navigated. The McGregor channel,

so called, is 1 500 feet wide at a medium stage of water, and the Prairie du Chien channel is 2 000 feet in width. The distance between the Wisconsin and Iowa shores, embracing the island to which reference has been made, is 7 000 feet, which corresponds to the length of the bridge.

The structure throughout is of ordinary piling, except across the navigable portions of the channels, which are covered by the pontoon draws. Each of these draws is a single float, 30 feet wide at the bottom, 6 feet deep, and 41 feet on deck, and 408 feet in length. The frame and bottom of the draw is of Norway pine, of heavy dimensions, and the deck of white pine. Each draw has five heavy bulkheads running the whole length, which are thoroughly bolted through and through. The track is regulated to the varying stages of the river by a system of blocking, confined in a frame and adjusted by means of hydraulic jacks. It may be observed that the range of variation between high and low water at this point is 22 feet. There is used in the construction of each of these draws about 600 000 feet of plank and timber.

The draw is operated by a steam engine of about 20-horse power, which communicates motion to a pulling chain passing over a drum, and stretching along the bed of the river, to suitable points above and below the draw, where it is securely fastened. The pontoon, when closed for the passage of trains, is held in position by a T-shaped wrought-iron shaft, 5 inches in diameter, which projects above the side of the draw into a timber frame, faced with iron and secured by a pier driven around it. This coupling, or fastening, is so arranged that it may be instantly attached or detached by a single person. The draw, when in position for the passage of trains, lies across the current of the stream at about a right angle, and when opened for the passage of river craft, comes to a rest parallel with the thread of the stream. The time occupied in opening or closing the draw is 3 minutes. The ends of each draw are adjustable to the approaches by trusses, 30 feet in length, composed of iron and of timber, by means of which the track upon the pontoon is securely connected with the permanent track. At each end of the draw shear booms rest on piers driven for the purpose, and extend at an easy angle to either shore, by means of which the largest rafts are safely guided through the draw-opening without the necessity of uncoupling.

The structure was built at about one-sixth of the estimated cost of an ordinary pivot bridge at the same point. A bridge of a similar style was erected last year across the Mississippi River between Wabasha,

PLATE XVIII
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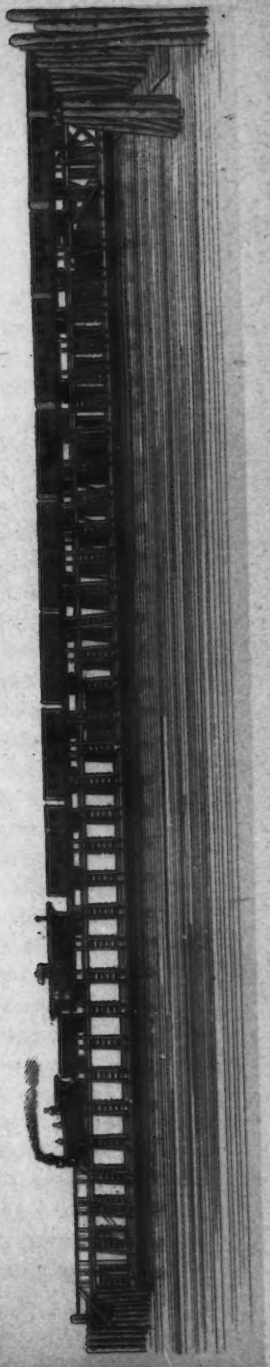
LAWLER ON
PONTOON BRIDGE.



Minn., and a point in Wisconsin near the mouth of the Chippewa River, and Congress has authorized the building of several others at various places on the Upper Mississippi.

In concluding this paper, I desire to express my sense of gratitude to D. J. Whittemore, Esq., M. Am. Soc. C. E., Chief Engineer of the Chicago, Milwaukee and St. Paul Railway Company, for his valuable advice and assistance during the planning and building of this structure.

DISCUSSION.

WILLIAM P. SHINN, M. Am. Soc. C. E.—I would state that I spent two weeks at Prairie du Chien about two years ago, and had occasion to observe the working of this bridge of Mr. Lawler's, at quite different stages of water. There was a considerable rise in the Mississippi while I was there, I think some 10 or 12 feet, and I was astonished at the facility with which the changes were made to correspond to the changes in the water level. It struck me that the economy of that mode of construction was very remarkable—bridging a stream like the Mississippi, and at the same time providing for the passage of all sorts of craft. I think Mr. Lawler, and those associated with him, are entitled to a great deal of credit for developing that kind of engineering in connection with this great water highway.

JOHN LAWLER, F. Am. Soc. C. E.—There is just one point to which I would like to draw attention. The idea of a pontoon couples with it the impression that there is a sort of disconnected series of bridges, and it might lead to the inference, perhaps, that the trains of the Chicago, Milwaukee and St. Paul Railway, which have been transferred over it for the last nine years, must necessarily have to be detached and transferred in fragments across the bridge. I desire to impress upon the minds of the members of the Convention that such is not the case; that full trains, drawn by the largest engines owned by that company, and arriving at the points named, are transported in precisely the same manner over this bridge that they would be over any other bridge.

J. P. FRIZELL, M. Am. Soc. C. E.—I would like to ask if the adjustment of the main track to the pontoon does not give rise to very steep grades?

Mr. LAWLER.—Such is not the case. The adjustments to the various levels of the water are made by the men who are otherwise necessarily employed upon the bridge, without the slightest hindrance to the trains,

and, of course, without the slightest additional expense. The track is so adjusted that just previous to the passage of the train the level of the pontoon track is slightly above the level of the permanent track, so that the weight of the engine, in entering upon the pontoon draw, brings the pontoon to a perfect level.

Mr. FRIZELL.—The entire bridge is lowered, then?

Mr. LAWLER.—The pontoon or draw part of the bridge gradually settles under the passage of a train about five (5) inches, but to an ordinary observer, or to the passengers on the train, this settling is not noticeable, on account of the manner in which the ends of the draw are connected with the permanent approaches of the bridge. These connections are made by two girders—one on each end of the draw—so adjusted that when the draw swings into place for the passage of a train the outer ends of the girders, which project 3 feet over the ends of the draw, are received by the permanent approaches at either end of the draw, thus affording them a solid foundation, and not only relieving the draw of a portion of the weight of the girders, and the ends of the draw for a distance of 30 feet from direct pressure, but also rendering more gradual the depression caused by the entrance of a train on the draw.

D. J. WHITTEMORE, M. Am. Soc. C. E.—Mr. Lawler has very kindly referred to me at the close of his interesting paper, and in complimentary terms that I think are not fully deserved. My remarks upon this subject will more particularly relate to the history in one marked instance of pontoons used for railway purposes.

Some of the older members present will call to mind that during the years 1848 to 1850 the Vermont and Canada and the Northern New York Railroads were under construction. These roads were built largely by Boston capital, and were intended to be operated in the interest of that city. When these lines were nearing completion it became necessary to devise some way to join them at the crossing of the outlet of Lake Champlain at Rouse's Point. The company controlling these two roads applied to the Legislature of New York for the privilege of constructing a draw span in the bridge which should connect its lines. The necessary authority for the construction of a draw-bridge of any reasonable span could not be secured. The president of one of these companies was the late Governor Charles Paine, uncle of the President of this Society. The chief engineer was the late Henry R. Campbell, a man of

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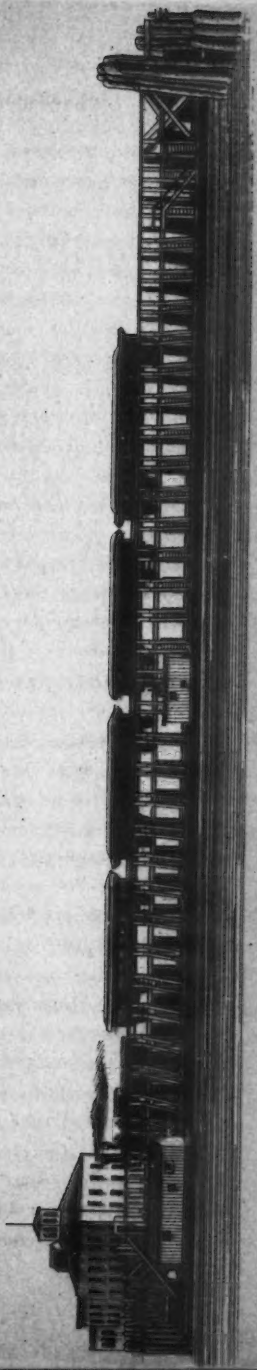
PONTOON BRIDGE.



extraordinary genius and capacity, and, in my opinion, one of the most remarkable engineers of his time. After defeat before the Legislature of New York it occurred to Mr. Campbell that the connection might be made by a pontoon, which should be operated by steam power, and in compliance with the legislative acts governing the operation of steamboats on Lake Champlain. A pontoon 303 feet long, about 30 feet wide, and 7 feet high, was constructed, and when it was launched, July 4th, 1851, I displayed sufficient lack of wisdom to be on board. The lake on the line of railway at this point is a little over one mile wide. Pile and timber approaches were built from each shore until a space equal to the length of the pontoon intervened. Suitable aprons for adjustment of track to the varying height of water were made at the end of each approach. For steam power to operate the pontoon there was used a dismantled locomotive, having the distinctive mark "Baldwin No. 4," but known throughout the line as the "Flying Dutchman," and I believe this was the original locomotive of that name in this country. This pontoon performed its duty until April 1st, 1868, and without accident of any kind, so I am informed.

Mr. Lawler has had charge of the transit of passengers and freight over the Mississippi at Prairie du Chien for the Chicago, Milwaukee and St. Paul Railway Company for many years, and about ten or eleven years ago, in conversation with me, he said: "I ought to do this work a great deal cheaper and safer than I am now doing it by steamboat and barges, and the idea has occurred to me that I should accomplish the desired end by the agency of a pontoon." I then gave him what little knowledge I possessed on the subject.

His pontoon, however, is so radically different from any built previously that it can be well said that Mr. Lawler is not only the designer and builder of it, but its originator. He constructed his pontoon 100 feet longer than the one at Rouse's Point. He arranges the approaches so as to adjust the track to a rise and fall of water of 20 feet. In Lake Champlain the extreme rise and fall hardly ever exceeds 7 feet, if I remember rightly. There is but a slight current at the outlet of that lake, while Mr. Lawler operates his pontoon against a very rapid current. Mr. Lawler has operated this device over nine years, and without accident of any kind to either person or property. If necessity should demand it, I am positive that by Mr. Lawler's device it would be practicable, using two pontoons, to open a clear water space of 1 000 feet in

a railway pontoon bridge in four minutes of time, and restore the same into position for traffic in about the same length of time.

NOTE.—The illustrations accompanying this paper have been prepared from photographs furnished by Mr. Lawler.

Plate XVIII.—Draw with freight train.

Plate XIX.—Draw with passenger train.

Plate XX.—Draw open.

Plate XXI.—Fig. 1.—View of draw above the track. Fig. 2.—Side view, showing the projecting T fastening in position as when pontoon is closed. The shaft of the fastening projects overboard 2 feet, and when the pontoon is closed the cross-piece rests behind heavy timbers, which are framed and bolted into a pile pier. When about to open, the cross-piece is moved by lever.

Plate XXII.—View under track.

PLATE XX
TRANS. AM. SOC. CIV. ENG'RS
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LAWLER ON
PONTOON BRIDGE.

FIG. 1

PLATE XXI
TRANS. AM. SOC. CIV. ENGRS
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LAWLER ON
PONTOON BRIDGE.

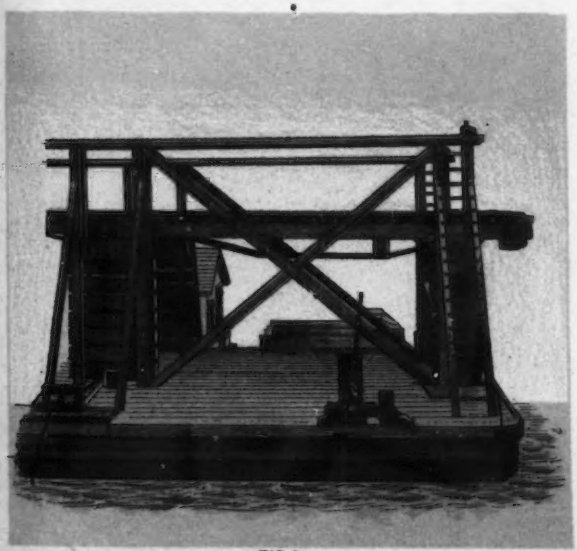


FIG 2

PLATE XXII
TRANS. A.M. SOC. CIV. ENG'RS
VOL. XIII NO. CCLXXVII
LAWLER ON
PONTOON BRIDGE.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLXXVIII.

(Vol. XIII.—March, 1884.)

TEMPERATURE OF WATER AT VARIOUS DEPTHS IN LAKES AND OCEANS.

By HAMILTON SMITH, Jr., M. Am. Soc. C. E.

READ APRIL 16TH, 1884.

WITH DISCUSSION.

In discussing the relative advantages of drawing water from a projected deep fresh-water reservoir in this vicinity, either from a depth of 170 feet, or from another point 60 feet below the surface, the writer expressed the opinion, that the temperature of the water at the greater depth would be much more constant during the year than at the shallower point; that is to say, the water at 170 feet would be very much cooler in the summer, and somewhat warmer in the winter months.

This opinion was based especially upon a personal experience with one of the North Bloomfield reservoirs in California; this reservoir was formed by a masonry dam about 100 feet in height, whose draught-

gates were some 90 feet below the top of the dam. The reservoir is generally nearly full in July, when the temperature of the air is often above 90° Fahr. in the middle of the day. The water near the surface soon becomes heated, so that it is too warm to be drunk with comfort, and not too cold for as lengthy swimming as the bather desires; at the same time the water drawn from the lower gates is almost icy-cold, so that it is pleasant for drinking, and too cold for anything but a single plunge in bathing. In the winter months, with a depth of 50 or 60 feet in the reservoir, the water from the gates is from 5° to 7° Fahr.* warmer than the stream water in the same locality, which is of great practical advantage to the North Bloomfield Company, as this comparatively warm water enters its canal—which is an uncovered ditch and flume—and retains more or less of this higher temperature for fifteen miles of its downward course, even during tremendous snow-storms, the snow melting as it falls into the water. In other canals in this neighborhood, where the water at the head is drawn directly from running streams, during heavy snow-storms the ditches or flumes will soon become choked or blocked by the falling snow, unless they are covered for almost their entire length.

As the difference between bottom and surface summer temperatures in this instance was of no particular practical importance, it has never been determined by a thermometer.

In lately discussing this question with several engineers and scientists, there seemed to be a general lack of information on the subject, the prevailing impression being that water at a depth of 170 feet would be only a trifle cooler in July than at the surface.

In order to discover whether this Bloomfield and other deep California reservoirs presented exceptional phenomena in temperatures, the writer has taken some pains to hunt up all the available published information on the subject, a *résumé* of which will be given in this paper.

The most elaborate observations at hand are those made in the Lake of Geneva, Switzerland, by F. A. Forel, and to be found in *Archives des Sci. Phys. et Nat., pp.* 501–516, *Paris, June,* 1880. Temperatures were taken from the surface to a maximum depth of 984 feet, from May,

* In this paper all temperatures will be given by the Fahrenheit scale.

1879, to January, 1880; the results are graphically shown on Fig. 1, Plate XXIII.

It will be noticed that the surface temperatures varied from 41° to 71.6°, while at a depth of 984 feet they remained constant at 41.4°; at the depth of 164 feet the range was only from 43.3° to 44.8°.

This lake rarely freezes, the recorded instances when it was partially frozen being in 1570, 1762 and 1805.

De la Bêche,* in September, 1819, found the surface temperature of the same lake to be 67.1°, and at a depth of 203 feet to be 43.9°; de Saussure† found several years earlier, in August, temperature at surface of 70.2°, and at a depth of 161 feet, 61°.

These observations, and also those upon other Alpine lakes by the same investigators, are given in part in graphic form on Plate XXIV.

Prof. Wm. Ripley Nichols, in 1878–9, observed the temperatures of Fresh Pond, Cambridge, Mass., at depths respectively of 2, 20 and 35 feet below the surface, for a continuous period of twelve months, the results being shown by Fig. 2, Plate XXIII. Even at this shallow depth of 35 feet, the variation in the year was only from 51° to 34½°, while 2 feet below the surface it was from 82½° to 33½°.

Prof. John Le Conte, in August, 1873, took the temperatures of Lake Tahoe, California, at various depths; an account of these and other observations being embodied in three very interesting articles, published in the *Overland Monthly*, San Francisco, November, 1883—January, 1884. At the bottom—1 506 feet below the surface—he found a temperature of 39.2° (4° centigrade), and at the surface 67°. Le Conte notes the fact that in Lake Tahoe the temperature does not decrease with shallow depths as rapidly as in the Lake of Geneva, and attributes this to the exceeding transparency of the waters of Lake Tahoe, which permits the heat rays to extend to greater depths than is the case in less translucent water. The clearness of Lake Tahoe is almost marvelous; when there is no wind to disturb the surface, it is wonderful at what great depths small objects can be distinctly seen. Lake Tahoe has never been known to freeze across, although the temperature of the air is doubtless often below 0°. Le Conte regards this fact as due to its great depth, high specific heat of water, and to wave agitation.

These observations, as well as those in various oceans, are shown on

* Ann. de Chim. et de Phys., p. 77. Paris, 1821.
† " " " " " p. 403. " 1817.

Plate XXIV, which gives the summer temperatures at different depths, as determined by the authorities referred to in this paper.

In ocean soundings we have the "Voyage of the *Challenger;*" observations made from the steamer *Blake*, and published in the United States Coast Survey Reports; and also unpublished information given to the writer by Coast Survey officials.

The *Challenger* found in latitude 37° 31′ south, longitude 36° 7′ west, at a depth of 16 050 feet, a bottom temperature of 30.9°, and in several other soundings 31.3° and 31.5°.

The *Blake* found north of St. Thomas, in the West Indies, 36¼° at a depth of 27 366 feet, which is notable as being the deepest sounding thus far made. At this point the surface temperature practically remains constant at 80°, or thereabouts.

The soundings of the *Blake*, taken in the Gulf Stream, off the Carolina coast, are especially interesting, as showing in this heated current, rapidly moving northward from the tropics, a very rapid diminution of temperature, even at comparatively small depths.

The explanation of this phenomenon of low summer temperatures at considerable depths, in bodies of fresh water, is, that water being densest or heaviest at about the temperature of 39.2° (4° C.), the surface water, which becomes cold in the winter, gradually sinks to and towards the bottom; water being a very poor conductor of heat, the strata at depths of 200 feet or more will retain during the summer this lower temperature, with but slight variations, although the solar rays may have heated the water at and near the surface up to 83°, as at Fresh Pond, and perhaps a few degrees higher were the body of water near this city.

According to Everett, the specific gravity of distilled water is as follows:

32°	.99987
39.2° maximum density	1.
50°	.99974
70°	.99800
86°	.99577

Water at 86° is therefore quite appreciably lighter than at 39.2°.

This theory seems to be insufficient to account for the very low temperature of 30.9° recorded by the *Challenger*, and that of 36.2° near

F. A. FOREL: 1879-80.

FIG. I. VARIATIONS, AT DIFFERENT DEPTHS, OF TEM

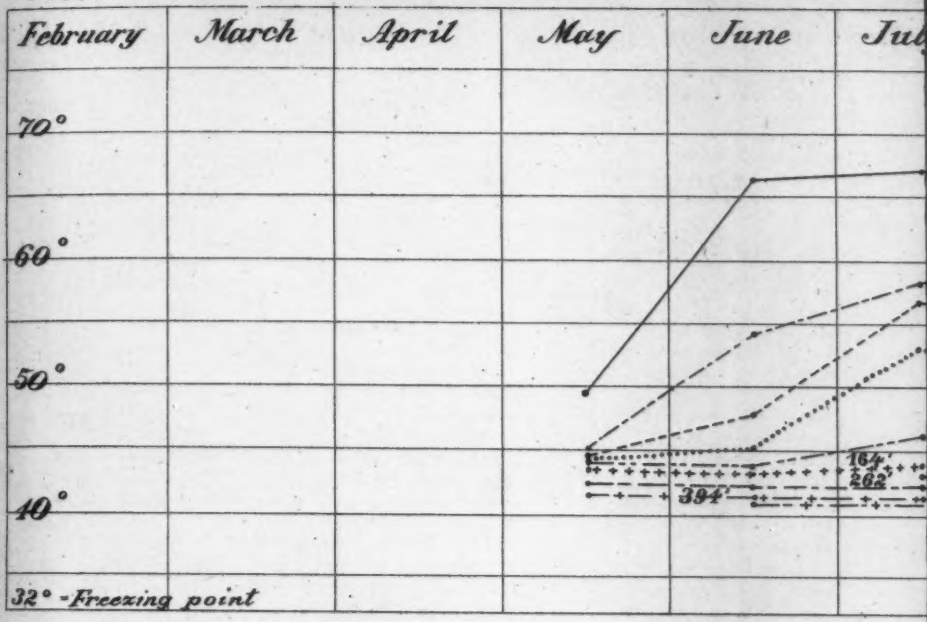
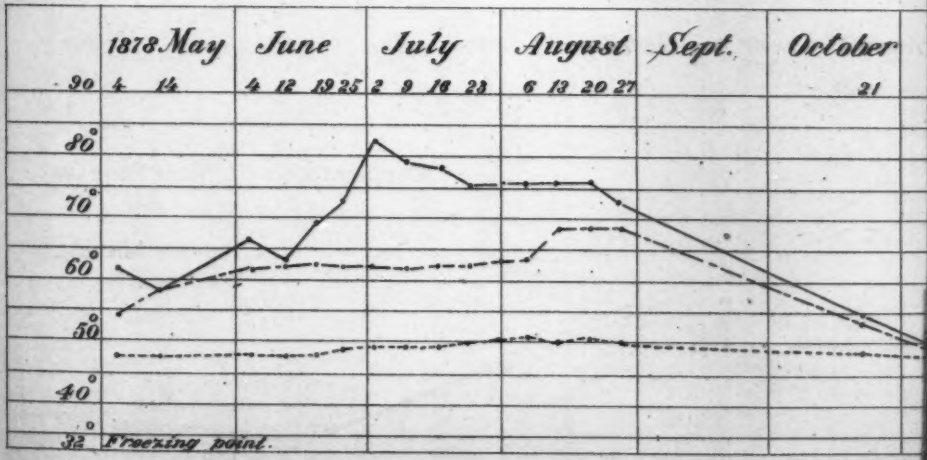
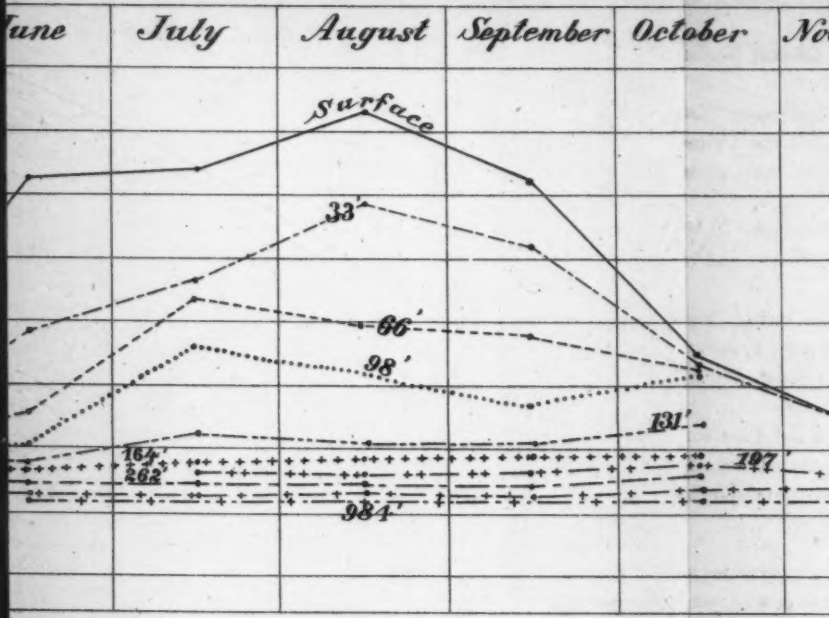


FIG. II



...THS, OF TEMPERATURE OF THE WATER IN THE LAKE OF



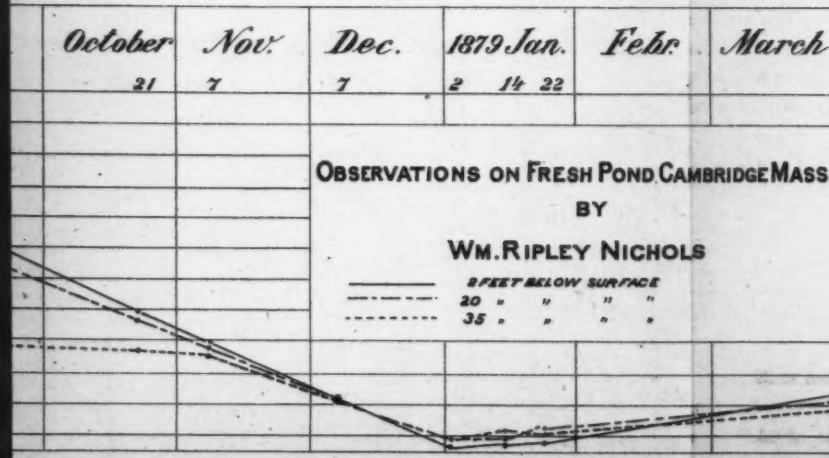


PLATE XXIII
TRANS. AM. SOC. CIV. ENGRS
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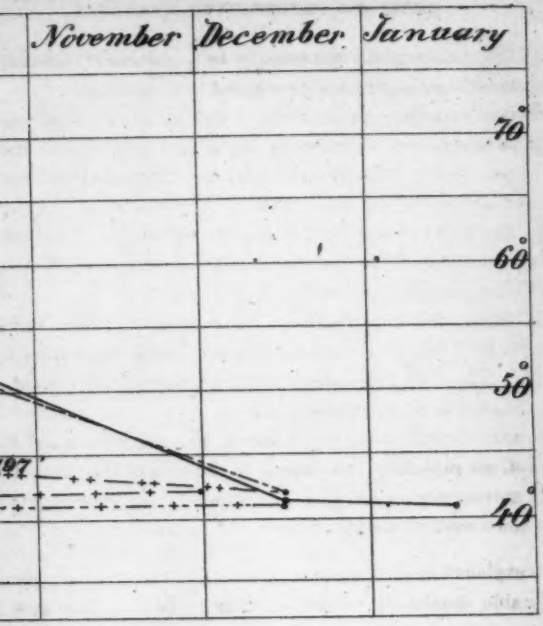
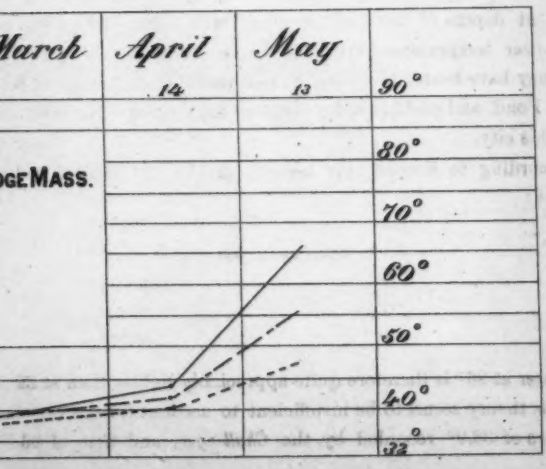
HAMILTON SMITH JR. ON
TEMPERATURE OF WATER

KE OF GENEVA.





GE MASS.

Saint Thomas; this latter sounding was probably in a very deep subaqueous crater, where the water would not be much affected by deep currents coming from the colder latitudes.

Possibly pressure, directly or indirectly, may be a factor in the problem.

It may be observed that there are great practical difficulties in the way of accurately determining temperatures at such enormous depths as those found by the *Challenger* and *Blake*. In the deep sounding off St. Thomas the pressure of the water amounted to nearly 12 000 pounds per square inch. Comparative tests, however, of the latest models of thermometers used by the U. S. Coast Survey show very satisfactory results.

From the foregoing it is evident that in a reservoir near New York the surface temperature may reach 85° in July or August, and go down to 33° or 34° during the winter; while at a depth of 170 feet the temperature will not vary greatly during the year from 45°, this being on the assumption that the reservoir remains full.

In cases where a large quantity of water can be obtained from depths of 60 to 170 feet, during the intensely hot summer weather of this locality, the resulting advantages of such cool water should have much weight in the determination of the point in the reservoir from which the water can be most advantageously drawn. Aside from the direct advantage of lower temperature, the water will doubtless be much freer from organic matter, or from organisms which rapidly develop when the temperature is 75° and upwards. In discussing the results to be expected in such a case, it, of course, is necessary to keep in mind that the bottom temperatures will become elevated, as the heated strata of water near the surface gradually find their way towards the lower portion of the reservoir.

A practical illustration on a small scale in regard to this same subject was lately given to me by a distinguished resident of this city, who generally spends his summer vacation fishing on a little lake in the northern part of the State. He observed that the fish were in greater abundance in the deep holes, and by a self-registering thermometer found, to his wonder, at depths of 100 or 110 feet a temperature of 40° to 45°, while at the surface it was 75° or 80°; this accounted for the presence of the fish. To utilize for himself this discovery, he proposes to build a fishing cottage on the shore near one of the deep holes, and

expects, by a pump, with a long suction pipe, to supply his party with cold drinking water, without the aid of an ice-house.

In order to obtain more thorough acquaintance with the lake temperatures, observations taken every fortnight, continuing over a period of 12 months, and taken simultaneously in two of the New York lakes, which are not far distant from each other, would be of much value. The question is of interest, not only to the pure scientist, but also to the hydraulic engineer.

DISCUSSION.

EDWARD P. NORTH, M. Am. Soc. C. E.—In extensive bodies of water there will probably be but little variation in temperature from the surface down to a point where agitation ceases. This in oceans may be as much as 30 feet.

HAMILTON SMITH, Jr., M. Am. Soc. C. E.—The effect of wave agitation in continually mingling the particles of water together near the surface is shown by the *Blake* soundings in the Atlantic on Plate XXIV, where the temperature remains unchanged for the first 5 fathoms.

Reference is made in the paper just read to the temperature of the water at the surface at various localities. I would like to know what is the surface temperature near New York.

GEORGE S. GREENE, Jr., M. Am. Soc. C. E.—The temperature near the surface of the water in New York Harbor near the wharves, as shown by records of daily observations for some ten years, varies from 31 to 80 degrees Fah. From the middle of June to September, it ranges from 75 to 80 degrees.

JOSEPH P. DAVIS, M. Am. Soc. C. E.—In conducting a series of experiments upon evaporation from water surfaces, the temperature of the surface was taken at the Beacon Hill reservoir, and at the Chestnut Hill reservoir of the Boston Water-Works. The highest of these temperatures recorded in the reports of the Boston Water Board is 78 degrees, in July, 1876. This, however, may be only a mean of the temperatures for that month.

Mr. DESMOND FITZGERALD, C. E. (by letter).—Reference to the daily observations shows that the highest surface temperature of the water in Chestnut Hill reservoir, during July, 1876, was 82 degrees, on the 14th and 15th of that month. August gave no temperature above 80 degrees maximum.

PLATE XXIV
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VOL. XIII NO. CCLXXVIII
HAMILTON SMITH JR. ON
TEMPERATURE OF WATER

TEMPERATURE OF WATER IN LAKES AND OCEANS AT VARIOUS DEPTHS

Fresh Water Lakes

Alpine Lakes

Geneva

DEPTHS BELOW SURFACE IN FEET	F. A. FOREL	F. A. FOREL	DE LA BÊCHE	DESAUSSURE	DESAUSSURE	DESAUSSURE	DESAUSSURE
	May	August	September	August	July	July	July
0	49.6°	71.6°	67.1°	70.2	63.5°	77.°	73.6
10							
20							
30	45°	64.4°					
40							
50							
60							
70	44.6°	54.9°					
80							
90							
100	44.4°	50.9°					
110			52.9°				
120							
130	44.2°	45.7°					
140							
150							
160				61.°(?)			
170	43.7°	44.4°	45.1°				
180							
190							
200		43.2°	43.9°				
300	43°	42.8°					
	42.6°	42.4°					
	42.3°	42.1°					
400	41.9°	41.9°			39.6°	44.2°	41.°
	41.5°	41.7°					
500		41.5°	43.5°				
	41.4°						
600							
700							
800	41.4°		43.5°				
900							
1000		41.4°	43.5°				

Constance, Maggiore, Neufchatel

DEPTHS BELOW SURFACE IN FEET	Constance	Maggiore	Neufchatel
	DESAUSSURE	DESAUSSURE	DESAUSSURE
	July	July	July
0	63.5°	77.°	73.6
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
110			
120			
130			
140			
150			
160			
170			
180			
190			
200			
300			
400	39.6°	44.2°	41.°
500			
600			
700			
800			
900			
1000			

Frozen Lakes

DEPTHS BELOW SURFACE IN FEET	Morat	Zurich
	FOREL	FOREL
	January	January
0	32.6°	32.4°
10		
20	35.4°	
30	35.6°	36.7°
40		
50	36.4°	
60		
70	36.5°	37.2°
80	36.5°	
90		
100	36.3°	37.8°
110		
120	36.6°	
130	36.9°	38.3°
140		
150		
160		
170		38.5°
180		
190		
200		38.7°
300		38 8°
400		39°
		39 2°
500		39.2°
600		
700		
800		
900		
1000		

Fresh Pond

Cambridge Mass.

DEPTHS BELOW SURFACE IN FEET	NICHOLS	NICHOLS
	January	July
0	33°	82½°
10		
20	34°	62°
30	35°	49°
40		
50		
60		
70		
80		
90		
100		
110		
120		
130		
140		
150		
160		
170		
180		
190		
200		
300		
400		
500		
600		
700		
800		
900		
1000		

Tahoe

Cal.

DEPTHS BELOW SURFACE IN FEET	LE CONTE
	August
0	67°
10	
20	
30	
40	
50	63°
60	
70	
80	
90	
100	55°
110	
120	
130	
140	
150	50°
160	
170	
180	
190	
200	48°
300	47°
	40°
400	45°
500	44°
600	43°
700	
800	41°
900	
1000	

Oceans

North Atlantic

Gulf Stream off Carolina Coast

DEPTHS BELOW SURFACE IN FEET	August	August
0	81.5°	83.5°
10		
20		
30	81.5°	
40		
50		
60	76.5°	
70		
80		
90		
100		
110		
120	70.2°	
130		
140		
150		
160		
170		
180	69°	68°
190		
200		
300		65.2°
400		
500		60.7°
600		56°
700		
800		
900		51°
1000		47°

Near Gulf-Stream off Fortress Monroe

DEPTHS BELOW SURFACE IN FEET	August	August
0	76.5°	77.5°
10		
20		
30	76.5°	75.2°
40		
50		
60	70°	69°
70		
80		
90		
100	68°	63.5°
110		
120	58°	57°
130		
140		
150		
160		
170		
180	54°	51.5°
190		
200		
300	53.5°	53.5°
400		
500	52.5°	52.5°
600	50.5°	49.5°
700		
800		
900	46.5	40°
1000	43.5°	43.2°

Nof St. Thomas

DEPTHS BELOW SURFACE IN FEET	PILLSBURY
0	78°
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
160	
170	
180	
190	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

off Florida

DEPTHS BELOW SURFACE IN FEET	HILGARD
0	79°
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
160	
170	
180	
190	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

South Atlantic

Challenger

DEPTHS BELOW SURFACE IN FEET	THOMSON LAT. 37½° S.
0	64.4°
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	63.9
160	
170	
180	
190	
200	
300	57°
400	
500	55.6°
600	54.1°
700	
800	53.2°
900	51.3°
1000	47.9°
	43.5°

Pacific

Tuscarora

DEPTHS BELOW SURFACE IN FEET	DAVIDSON Winter
0	55.4
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
160	
170	
180	
190	
200	
300	
400	
500	
600	46.1°
700	
800	
900	44.3°
1000	43 4°

100	44.4°	50.9°						36.3°	37.8°			55°								100
110			52.9°																	110
120								36.6°					70.2°		58°	57°				120
130	44.2°	45.7°						36.9°	38.3°											130
140																				140
150												50°						63.0		150
160																				160
170	43.7°	44.4°	45.1°	61.°(2)					38.5°											170
180													69°	68°	54°	51.5°				180
190																				190
200		43.2°							38.7°			48°								200
300	43° 42.6° 42.3°	42.8° 42.4° 42.1°	43.9°						38 8°			47° 40°		65.2°	53.5°	53.5°		57°		300
400	41.8° 41.5°	41.9° 41.7°			39.6°	44.2°	41.°		39° 39 2° 39.2°			45°								400
500		41.5°	43.5°									44°		60.7°	52.5°	52.5°		55.6°		500
600	41.4°											43°		56°	50.5°	49.5°		54.1°	46.1°	600
700																				700
800	41.4°		43.5°									41°						53.2°		800
900														51°	46.5	40°		51.3°	44.3°	900
1000		41.4°	43.5°																	1000
1500														47°	43.5°	43.2°		43.5° 41.4°	43 4°	1500
2000												38 2°								2000
3000															40.5°	40.7°		40.5°		3000
4000															40°	39.7° 39°	44½° 44°	39.2° 37.4°	40°	4000
5000																38.7° 38.5° 38.5°	39½°	36.5°		5000
6000																		36.5° 36.1°		6000
7000																				7000
8000																				8000
9000																				9000
10,000																				10,000
15,000																		30.9°		15,000
20,000																				20,000
25,000																	30 25°			25,000
30,000																				30,000

J. J. R. CROES, M. Am. Soc. C. E.—In December, 1883, in the Harlem River, when there was no ice at the surface, a diver brought from the bottom, about 30 feet from the shore at the end of Second avenue, 32 feet below high water level, masses of frozen gravel. The temperature of the salt water of the river was about 28 degrees at the surface. At the point where the ice was found, the bottom had been dredged to a depth of about 12 feet, through mud and into sand and gravel.

Borings near this point before the dredging was begun showed the existence of springs of fresh water rising through the river bottom.

EDWARD P. NORTH, M. Am. Soc. C. E.—The water of Lake Superior, at Duluth, is too cold for bathing at any season of the year. Does any one know the variations of temperature there at various depths?

HAMILTON SMITH, Jr., M. Am. Soc. C. E.—Professor Nichols, in his "Temperatures of Fresh-water Lakes and Ponds, Boston, 1881," gives a table showing temperatures in Lake Superior, determined by the United States Lake Survey in 1871. It is substantially as follows:

DATE.	LOCATION.	DEPTH IN FEET TO BOTTOM.	TEMPERATURE.	
			AT SURFACE.	AT BOTTOM.
1871.				
Aug. 7.	Lat. 46° 53′ to 47° 23′	762	56.5°	38.8°
	Long. 86° 43′ to 86° 15′.....	786	50.1°	38.8°
		444	50.8°	38.8°
" 11.	Lat. 48° 18′, Long. 86° 15′.....	354	55.8°	41.3°
" 15.	Lat. 48° 20′ to 47° 45′.....	630	49.7°	39.0°
	Long. 87° 03′ to 87° 06′.....	1 008	49.2°	39.0°
		822	52.2°	38.9°
" 18.	Lat. 48° 09′ to 47° 36′.....	282	51.8°	36.8°
	Long. 88° 15′ to 87° 42′.....	774	52.7°	38.9°
		492	51.5°	39.0°
" 22.	Near Copper Harbor.....	888	.....	38.7°
		366	55.3°	39.2°
		120	51.3°	39.7°

D. J. Whittemore, President Am. Soc. C. E.—During the summer months, when the water of Lake Michigan is comparatively warm at the surface, cold water is frequently obtained by fishermen by sinking from a boat a corked jug to some depth in the lake and then pulling out the cork and letting the jug fill with the water at that depth. The water thus secured is very cold and refreshing.

Robert L. Harris, M. Am. Soc. C. E.—In connection with this question of temperatures, it seems strange that that of water should decrease so greatly with increased depth—nearly down to the freezing point at the enormous depth of 27 000 feet—while precisely the reverse is true in regard to the earth's surface, as shown by deep mines and wells. I would like to have some information on this latter point from some of the gentlemen I see here, who are familiar with mines.

Hamilton Smith, Jr., M. Am Soc. C. E.—The temperature of the earth, as shown by deep mines, varies very greatly in different parts of the world, and in different geological formations. The general law is, that the temperature increases with depth, but even as to this there are exceptions. At the New Almaden quicksilver mine, in California, in one of the drifts, at a depth below the surface of 600 or 700 feet, the temperature was very high—if I remember correctly, from 115° to 120° Fah. In the deepest part of the same mine, on the 1 700 and 1 800 foot levels, the temperature is very pleasant, being probably less than 80°, and this at a depth of 500 feet or more below sea level.

The Comstock mines in the State of Nevada are perhaps the hottest in the world; the greatest depth there attained is a little over 3 000 feet, and there has been a general, constant increase in temperature with greater depths. This question of heat in the Comstock Lode has been discussed at length by John A. Church in "The Comstock Lode" (New York, 1879), and G. F. Becker, in "Geology of the Comstock Lode" (Washington, 1884).

At the Eureka mines in the same State, and at about the same elevation above sea level, there seems to be but little increase in temperature with greater depths, the air in the 1 200 foot level of the Richmond mine being apparently nearly as cool as in the workings only 100 feet below the surface. The ore in the Eureka district is found in limestone, with quartzite and shale, or stratified limestone, forming the walls.

These facts tend to show that changes in the temperature of the

earth's crust are very often due to local causes, and are probably often produced by chemical forces still in operation.

From my own observations in mines in different latitudes, from near the equator to 55° north latitude, I should judge that the normal temperature of the earth at a depth of 50 or 60 feet, or at a point where it is not affected by the monthly changes of the aerial temperature, is approximately the mean annual temperature of the air at the particular place. Hence the ordinary temperature of spring or well water should correspond, in a measure at least, with this annual mean.

It is difficult to obtain in mines the exact temperature of the rock, as the cool air used for ventilation soon affects the surfaces exposed. In some of the deepest Belgian coal mines, with depths of over 2 000 feet, I understand that it is impracticable to work them extensively at first, some time being required to allow them to thoroughly cool.

In connection with hot mines, it will be of interest to mention a fact in regard to the Comstock workings. In one of the very hot drifts some years since, the miners could only remain for a few moments at a time, and as an experiment some iced water was given to them; it produced no ill effects, but on the contrary enabled the men to work to much better advantage; since then iced water is furnished to the workmen in all these mines, and is drunk *ad libitum* with apparently no bad results upon health.

Mr. Dorsey is very familiar with the Comstock mines, and doubtless he can give us more detailed information in regard to their changes in temperature.

EDWARD B. DORSEY, M. Am. Soc. C. E.—The mines on the Comstock vein, Nevada, are exceptionally hot; at depths of 1 500 to 2 000 feet, the thermometer, placed in a fresh-drilled hole, shows 130° Fah. Very large bodies of water have run for years at 155° temperature, and smaller bodies at 170°, sufficiently hot to scald the person and to destroy human life. Where the air is not freshened by ventilation, the steam escaping from the hot water saturates it with moisture, making it much more oppressive than if it was dry. There have been fatal accidents from falling into this hot water, or from being overpowered by the heat in the workings, owing to accidents to the ventilating machinery.

The temperature of the air is kept down to about 110° by forcing down fresh air, cooled over ice, from the surface.

I have seen no mining operation in any part of the world where so much money is spent in the vain effort to keep cool.

Captain Geo. M. Wheeler, U. S. Engineers, estimated the heat extracted annually from the Comstock, by means of the water pumped out and cold air forced in, as equal to that generated by the combustion of 55 560 tons of anthracite coal, or 97 700 cords of wood.

It has been generally asserted, as an axiom, that the heat increased 1° Fah. for every 60 feet in depth below the earth's surface. In my experience I have found this to be incorrect, varying very much in different geological formations.

About 15 miles from the Comstock mines there are hot springs, some discharging boiling water, with intermittent or geyser action.

The following measurements of temperature were made by Mr. Chas. Forman, Superintendent of the Overman mine, while sinking the new "Forman shaft." This shaft is being sunk so as to cut the vein at about 4 500 feet in depth. It was commenced about 4 000 feet east of the outcrop of the vein, consequently these measurements were made entirely outside of the vein. At each 100 feet in depth three holes were drilled at least 3 feet deep, thermometers placed in each, and the holes then plugged up with clay. At the end of 12 hours the thermometers were read as follows:

100	feet deep,	53	degrees Fah.
200	"	56.3	"
300	"	59.6	"
400	"	62.8	"
500	"	66.1	"
600	"	69.3	"
700	"	72.6	"
800	"	75.8	"
900	"	79.1	"
1 000	"	82.4	"
1 100	"	85.6	"
1 200	"	88.9	"
1 300	"	92.1	"
1 400	"	95.4	"
1 500	"	98.6	"
1 600	"	101.9	"
1 700	"	105.2	"

1 800	feet deep,	108.4	degrees Fah.
1 900	"	109.5	"
2 000	"	112.5	"
2 100	"	115.4	"
2 200	"	118.4	"
2 300	"	121.2	"

The temperature increases more rapidly near the surface than it does below, as will be seen by the following comparisons :

100 to 1 000	feet deep,	increase	1°	in 29	feet.
100 to 1 800	"	"	1°	in 30.5	"
100 to 2 300	"	"	1°	in 32.3	"

The temperature was observed while sinking the two following shafts on the Comstock :

Combination Shaft—

Temperature of rock		100	feet deep,	53	degrees Fah.
"	"	1 476	"	103.4	"
"	"	2 230	"	119.6	"

Yellow Jacket Shaft—

Temperature of rock		100	feet deep,	53	degrees Fah.
"	"	845	"	81.4	"
"	"	2 017	"	120.5	"

These shafts are in the trachyte hanging wall of the vein, 4 or 5 000 feet distant from the outcrop.

The Yellow Jacket shaft is about 1 300 feet from the Forman shaft; the Combination shaft is about 1 mile distant. Higher temperature of rock is found nearer the vein than is shown by these distant shafts.

There are very little data published, and those very incomplete, upon the temperature of the interior of the earth.

The following table gives the temperatures of the rock and water in some of the most noted mines, tunnels and artesian wells, which, however, is not complete or strictly reliable, as few persons will take the trouble necessary to get the temperature of the rock at the different depths in the same mine, which is the only way of estimating the increase of heat in depth. For the want of this care, no two persons give the same result.

The temperature of water either in mines or artesian wells, or from springs, does not necessarily give the temperature of the rocks in the

immediate vicinity of its discharge, though it must have passed through rocks at least equal to it in temperature somewhere in its subterranean circulation. The artesian wells in Chicago show the extent of the internal circulation of water; it is asserted that this water must come from over 100 miles, in order to get the height at which it is discharged.

In the Comstock the water is from 30° to 40° hotter than the adjacent rock; in the St. Gothard tunnel it is 6° warmer. In hot springs, boiling water is discharged through comparatively cool rocks.

The Eureka mines, at Eureka, Nevada, in limestone formation, about 6 000 feet above the sea, are very cool at the lowest level, 1 200 feet deep. I have no figures, but the temperature at the bottom is very pleasant, even when wearing the ordinary clothing worn on the surface.

In the following table the two coolest mines or tunnels are in limestone, namely, Chañarcillo mines and Mt. Cenis tunnel; and the two hottest are in trachyte and the "coal measures," viz., the Comstock mines, in trachyte, and the South Balgray, in the "coal measures."

The coolness or heat being estimated by the number of feet in depth to increase the temperature 1°.

The coal mines of Belgium are very hot, but I have no reliable data about them.

The difference of heat in different formations is shown very plainly in the Mt. Cenis and St. Gothard tunnels. These two works are comparatively close together, in the same chain of mountains, and about the same elevation above the sea. The former is in calcareous formation, increasing 1° in temperature for every 102 feet in depth. The latter is in granite, gneiss, and mica schist, increasing 1° in every 88 feet in depth.

The difference would probably be much greater if it was not for the abundance of water in the St. Gothard, which amounted to 4 000 000 gallons daily. The formation was full of seams which, apparently, extended to the surface, giving free passage for the surface water, which doubtless cooled the rock.

My experience is confirmed by the accompanying table, that limestone is the coolest formation.

TEMPERATURE OF DEEP MINES, TUNNELS AND ARTESIAN WELLS.

Name.	Locality.	Elevation above Sea.	Depth below Surface.	Depth below Sea.	Temperature Fah.			Average Number of Feet for each Degree of Increase.		Geological Formation and Remarks.
		Feet.	Feet.	Feet.	100 ft. Below Surface. Degrees.	Water. Degrees.	Rock. Degrees.	Water.	Rock.	
Dakensfield	Near Manchester, England	.....	2 040	.....	.....	.....	.....	.....	83	Coal measures.
Rose Bridge	Near Wigan, "	.....	2 445	.....	.....	.....	92°	.....	71	" Temperature 483 ft. deep, 63.2°.
South Balgray	Near Glasgow, "	.....	525	.....	.....	.....	.....	.....	41	"
Levant Tin and Copper Mine	Cornwall, " Surface	180	1 380	1 200	.....	78°	80	.....	44	Granite and killas.
Consolidated Mines	" " "	318	1 740	1 422	.....	.....	86	.....	48	Killas. — British Association,
" "	" " "	318	1 740	1 422	.....	.....	92	.....	43	In vein. In killas. — Vol. 6, p. 133.
Tresavean Copper	" " "	348	1 572	1 248	.....	.....	82.5	.....	47	Granite.
United Mines	" "	.....	1 500	.....	.....	115	.....	22	.....	Formation not stated—probably granite.
Chañarcillo	Chili "	5 500	1 550	.....	61°	.....	75	.....	107	Oolitic limestone, observed by E. B. Dorsey.
Combination Shaft	Comstock Vein, Nevada... "	5 600	2 230	.....	53	.....	119.6	.....	32.3	The surface temperature is assumed to be the same as that of the Forman Shaft, 53°
Yellow Jacket "	" " ... "	5 400	2 017	.....	53	.....	120.5	.....	30	
Forman "	" " ... "	5 400	2 300	.....	53	.....	121.2	.....	32.6	This and the two preceding are in the trachyte hanging wall of the vein.
Mt. Cenis Tunnel	Alps, Europe	4 246	5 084	.....	35	84	84	.....	102	Calcareous.
St. Gothard Tunnel	" "	3 781	4 418	.....	37.7	93	87	.....	88	Granite gneiss, gneiss and mica schist.
Grenelle, Artesian Well	Paris, France	.....	1 797	.....	.....	82	.....	60	.....	Clay, sand, chalk, &c.
Kentish Town, Artesian Well	London, England	.....	1 100	.....	.....	.....	.....	54	.....	London chalk, clay, sand, &c.
St. Louis, "	Missouri, United States	.....	2 199	.....	.....	73.4	.....	83	.....	Limestone. Salt water.
" "	" "	.....	3 844	.....	.....	105	.....	76	.....	" lower 40 ft. in granite.
Charleston, "	South Carolina, "	.....	1 250	.....	.....	87	.....	52.5	.....	Cretaceous, sandstone, marl, &c.
Louisville, "	Kentucky, "	.....	2 036	.....	.....	76.5	.....	96	.....	Limestone.
Columbus, "	Ohio, "	.....	2 775	.....	.....	91	.....	73	.....	"
Kissingen, "	Bavaria, Germany	.....	1 878	.....	.....	66	.....	113	.....	Formation not stated—lowest 138 ft. in salt.
Sperenberg, "	Near Berlin, "	.....	4 163	.....	55	118	.....	65	.....	" " Salt deposit.

The data of the Rose Bridge Colliery is taken from J. Arthur Phillips, who does not state whether the temperature given is of the water or rock. Others make the temperature greater, the increase being 1° in 54 feet.